material collected and presented in the two volumes and the atlas of this book, give us, first of all, a most important *aperçu géologique* of the Danakil country, French Somaliland, and southern Abyssinia as far as Addis-Abeba, and a petrographical study of the same regions, with analyses of the rocks and minerals collected, and many photographs to show the types of landscape. These photographs are most conscientious, but the country presented to our eyes between Addis-Abeba and the Gulf of Aden is certainly one of the least alluring of all Africa. The Sahara Desert is much more attractive from the painter's point of view.

Some beetles were collected and are described. There is a most important article (taking up a considerable proportion of the second volume) on the anthropology and ethnography of southern Abyssinia, by Dr. R. Verneau, of the Paris Museum of Ethnography. This is accompanied by admirable photographs of skulls, of clothing and adornments, of musical instruments, pottery, jewellery, and horse harness; but the photographs taken by the expedition of living human types are, with one or two exceptions, not good or trustworthy, since they have been too much touched up in order to make them presentable pictures, or else they are very minute. The author of this section (Verneau) would seem to have arrived at the following general conclusions:—That in the portions of Abyssinia and northern Ethiopia in which the Duchesne-Fournet expedition collected skulls and took careful measurements of the living body, there were, besides the pure-blooded Negro, three distinct human types:—(1) The *Amhara* or *Abyssinian* (with which might also be grouped the *Gala*; (2) the *nigritised Abyssinian* (simply the result of ancient and modern intermixture between the Hamite—Abyssinian, Gala—and the Negro); and (3) a most interesting form, the *Berber* (this is a short title for the descriptive term given by Dr. Verneau, who calls it, "Type Abyssin clair, à cheveux lisses ou ondulés," and elsewhere, "Berbère"). This "third ethnic element" he describes as "very different from those which I have already set apart." It is one which has made its influence felt in Abyssinia, but, like the Negro element, it has crossed with the Hamite or Ethiopian (type No. 1), and as the result of this mixture its characters have become sensibly attenuated. "Nevertheless, one may affirm that this type No. 3 is of a fair complexion, slightly *cuivré*, and is further notable because it has evidently lightened the complexion of the skin in 13·5 per cent. (approximately) of the actual population." "Type No. 3," he goes on to say, "has blue eyes, or must have had blue eyes originally; for one could scarcely derive the blue, grey, or green iris (which is that we have noted in the proportion of 11·7 per hundred amongst modern Abyssinians) from the Ethiopian or the Negro. It is also type No. 3 which has certainly introduced the smooth or very slightly undulating hair, which has been found in 13·2 per cent. of the individuals under examination. On the other hand, this light-skinned race has not introduced tall stature amongst the people, but rather lessened the stature of the Abyssinians as compared with that of the Hamite and negroid races farther south."

In this race, Dr. Verneau apparently sees a marked resemblance to the Kabail of Abyssinia. One of the skulls depicted seems to display affinities with the Cro-magnon race of Western Europe.

There is a most comprehensive bibliography of Ethiopia in this work under review, a work which whets one's appetite for a complete examination of Abyssinia.

H. H. JOHNSTON.

THE SYSTEMATIC MOTIONS OF THE STARS.[1]

A SYSTEMATIC character in the proper motions of stars was discovered by Herschel, and accounted for by the motion of the solar system in space. Herschel's conclusions were for a time disputed by Bessel, but were confirmed by Argelander, and have since been generally accepted. In the last quarter of a century many determinations of the direction of the solar motion have been made, but the results have not shown that accordance which might have been anticipated. Particularly noticeable are the different results obtained from the proper motions determined by Auwers of the stars observed by Bradley in 1750, and re-observed about 1860, according to the method employed. Applied to these stars, the mathematical methods of attacking the problem developed by Airy and Argelander place the solar apex, or point to which the sun is moving, in declination +35° or thereabouts, while Bessel's method places it at −5°. In 1895, Dr. Kobold directed attention to these discrepancies, which seem to point to an error in the fundamental hypothesis underlying these methods of determining the direction of the solar motion. These methods are based on the assumption that the "peculiar" motions of the stars are haphazard, and have no preference for any particular direction or directions in space.

As an outcome of prolonged study of the subject, Prof. Kapteyn announced, in 1905, at the meeting of the British Association in South Africa, that this hypothesis was untenable. He used the well-determined proper motions of 2400 stars extending from the pole to 30° south of the equator given in Auwers-Bradley. Dividing this area of the sky into twenty-eight regions, he determined the directions of the apparent proper motions of the stars in each region, and found that they showed a preference for *two* special directions and not for one only. When these favoured directions for the twenty-eight areas were plotted on a sphere, they were seen to converge to two points. Convergence to a point on the sphere indicates that the apparent linear motions of the stars are parallel, just as the radiant point of a meteor stream indicates the direction in which the meteors are all apparently travelling. Relatively to the sun, therefore, the stars are moving in two streams, inclined at a considerable angle to one another; these motions are apparent only, and, when the solar motion is subtracted, are resolvable into two streams moving in diametrically opposite directions, relatively to the centre of gravity of the stars. Kapteyn showed that the stars were equally distributed among the two streams, and that their relative motion was in a line in the plane of the Milky Way, directed towards the star ξ Orionis (R.A. 91°, decl. +13°) and the opposite direction. The apparent motions of the stars are thus resolvable into a combination of (1) a haphazard motion, (2) the reversed solar motion relative to the centre of gravity of the stars, and (3) the stream movement in the direction of ξ Orionis and the opposite direction. It was pointed out by Kapteyn that the determinations of the solar motion made by Airy's method, the one most generally adopted by astronomers on account of its simplicity and convenience, were not much in error, in spite of the systematic character of the motion of the stars in these two streams. For the equations which result from Airy's method agree closely with those of a valuable method of determining the solar motion due to Bravais, which does not assume the haphazard character of the peculiar motions of the stars. But an entirely new fact in stellar astronomy has been elicited in the discovery of the systematic movements towards and away from ξ Orionis.

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[1] (1) J. C. Kapteyn, Reports of the British Association for the Advancement of Science, 1905, p. 257.

(2) A. S. Eddington, Monthly Notices of the Royal Astronomical Society, 1906, vol. lxvii., p. 34, and vol. lxviii., pp. 104 and 588.

(3) K. Schwarzschild, Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, 1907, p. 614, and February, 1908.

(4) S. Beljawsky, Astronomische Nachrichten, Band clxxix, p. 293.

(5) F. W. Dyson, Proceedings of the Royal Society of Edinburgh, 1908, vol. xxviii., part i., p. 231; 1909, vol. xxix., part iv., p. 376.

Mr. Eddington introduced a precise mathematical definition in place of the somewhat nebulous phrase star-stream. A "drift of stars" is defined as a group of stars the velocities of which relative to some system of axes are quite haphazard. The velocity of the "drift" is the velocity of the system of axes, while the "peculiar" velocity of a star is its haphazard velocity relative to the system of axes. Haphazard is defined as a distribution of velocities, according to Maxwell's law for the molecules of a gas. Formulæ are then developed to give the distribution of the directions of proper motions in any small area of the sky which would arise from the projection on the face of the sky of a star drift with a given mean peculiar velocity and a "drift" velocity given in magnitude and direction. Mr. Eddington applied his method to the consideration of the proper motions in Groombridge's catalogue, recently determined at Greenwich by Messrs. Dyson and Thackeray. The catalogue contains about 4500 stars within 52° of the North Pole, a large proportion being between magnitudes 7 and 9. Comparing the actual distribution with a theoretical one, based on the assumption that the stars form two drifts, he found close accordance. The stars were equally divided between two "drifts" the apparent directions of which were in good agreement with Kapteyn's results. The two streams did not show any distinctive features, each contained bright and faint stars, and stars of all types of spectrum, and, further, the mean distances from the sun of the stars contained in the two "drifts" were the same. Additional confirmation was obtained from 1200 stars within 10° of the North Pole, the proper motions of which had been determined by comparison of the Greenwich positions in 1900 with those found by Carrington in 1855. In a later paper, and by a somewhat different method, about 2000 fairly bright zodiacal stars were also examined.

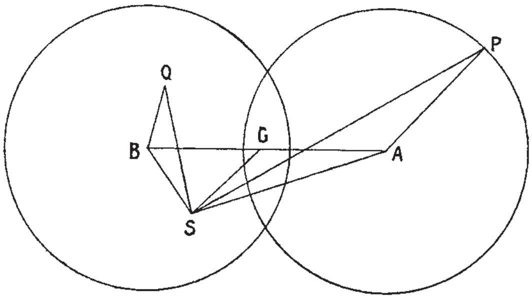

FIG. 1.—Velocity diagram according to Eddington's hypothesis.

According to Mr. Eddington's determination, the velocity of one stream relatively to the sun may be represented by SA, and that of the other by SB, while the haphazard velocities of the stars composing the streams are equally in all directions from the centres A and B, and their mean values are represented by the radii of the two spheres. The solar velocity relative to the centre of gravity of all the stars is represented by SG, and the rates at which the streams are separating by AB. If SP denote the velocity of one star relatively to the sun, this may be analysed into SA, the "drift" velocity, and AP, the "peculiar" velocity (which in this instance has its mean value); the drift velocity SA may be analysed into SG, the solar motion, and GA, the velocity of the stream. Similarly, SQ, the velocity of another star, may be resolved into a component of the second stream, the peculiar velocity of which is BQ, or only half the mean value.

Prof. Schwarzschild assumes that the "peculiar" motions of the stars do not obey Maxwell's law, but a slightly modified law in which the resolved parts of the velocities in one direction are all increased in a definite proportion, thus giving a spheroidal instead of a spherical distribution. When combined with the solar motion, this distribution of "peculiar" velocities gives two favoured directions for the proper motions of the stars included in any small area of the sky, and has the advantage of representing the stars as a single instead of a dual system. Applied to the Greenwich-Groombridge proper motions, the assumption shows a very satisfactory accordance with facts. According to Prof. Schwarzschild, the observed proper motions of these stars would be produced by a velocity of the solar system SG and "peculiar" velocities of the stars the mean values of which in different directions are radii of the prolate spheroid ABA′B′. Thus the velocity SQ of a star is resolvable into SG, the solar motion, and GQ, the "peculiar" velocity. In this instance the "peculiar" velocity is one-half the mean "peculiar" velocity belonging to the direction GQ. In his second paper Prof. Schwarzschild develops his theory with great mathematical elegance so as to make it applicable to cases where the number of stars per unit area is small. In this form it is applied by Mr. Beljawsky to the stars of large proper motion in Prof. Porter's catalogues, although its application is not free from objection, as these stars were selected on account of their large proper motion, while the method is strictly only applicable to unselected proper motions.

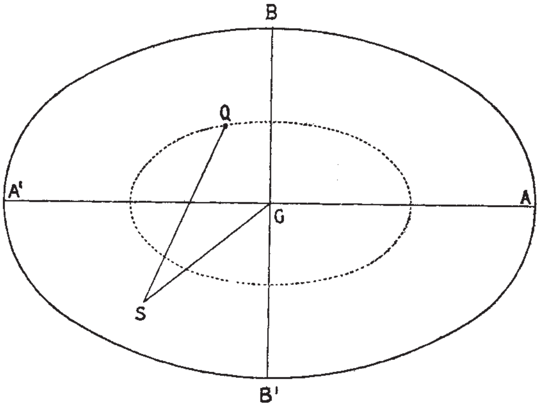

FIG. 2.—Velocity diagram according to Schwarzschild's hypothesis.

Prof. Dyson collected all the proper motions greater than $20''$ a century from various sources, and by a simple graphical method determined the favoured directions of motion. Partly owing to the small effect of accidental error of observation on the direction of the proper motion of these stars, and partly because only large proper motions were considered, the two apparent star streams were shown with great clearness. In the large majority of cases it was possible to assign individual stars to one or other of the two streams, and thus a verification was obtained of the result that the two streams showed no difference as regards the magnitude or type of spectrum of the stars in them. Of 1800 stars examined, 1100 belonged to the first stream, 600 to the second, and the remaining 100, which could not be assigned to either, showed no motion of a systematic character. The large proportion of stars belonging to the first stream arises from the mode of selection according to the magnitude of proper motion. Kapteyn's and Eddington's result, that when stars are taken without selection they are equally divided between the two streams, is used to determine the ratio of the stream velocities. When this is determined the apparent movement in two streams, as seen from the earth, is replaced by the solar motion and two streams moving in opposite directions relative to their centre of gravity.

There is at first sight considerable difference between Kapteyn's description (followed by Eddington and Dyson) of the systematic movements of the stars, and that of Schwarzschild. The dual character of Kapteyn's system should not be unduly emphasised. Division of the stars into two groups was incidental to the analysis employed, but the essential result is the increase of the peculiar velocities of stars towards one special direction and its opposite. It is this same feature, and not the spheroidal character of the distribution, which is the essential of Schwarzschild's representation. The results obtained by the two methods agree very closely. Defining the "apex" as the direction of the sun's motion relative to the centre of gravity of the stars, and the "vertex" as the direction of motion of one stream relatively to the other (Kapteyn) or the major axis of Schwarzschild's spheroid, the accordance of the different results is shown in the following table:—

	Apex		Vertex	
	R.A.	Dec.	R.A.	Dec.
	°	°	°	°
Kapteyn—Bradley stars	—		91	+13
Eddington—Groombridge stars ...	266	+31	95	+ 3
Schwarzschild—Groombridge stars ...	266	+33	93	+ 6
Dyson—Stars of large proper motion.	281	+42	88	+24
Beljawsky—Porter's stars	281	+36	86	+24
Eddington—Zodiacal stars	—		109	+ 6

It may be noticed that the Groombridge stars gave almost identical results by the methods of Eddington and Schwarzschild, and that Beljawsky and Dyson, whose material was very similar, obtained results in close accord.

Although attention may be directed to Kapteyn's observation that the vertex lies in the plane of the Milky Way, it is too soon to offer any explanation of these remarkable movements of the stars. To have disentangled them from the irregular proper motions of the stars is itself a very important step. By clearing up the difficulty in the anomalous results previously found for the direction of the solar motion, and by the discovery of systematic movements in which all the stars share, Prof. Kapteyn has made the most important contribution to this branch of astronomy since the time of Herschel.

F. W. DYSON.

THE SEA OF ARAL.

RECENT explorations in Central Asia, and the evidence accumulating from many quarters of general desiccation of that area within historic times, give special interest and value to anything in the shape of observations of even approximate precision which point towards an opposite conclusion, or to a conclusion that variations in the amount of precipitation, where they occur, are more or less local and constitute merely a phase which, although it may be of relatively long period, does not represent continuous progressive change. The work carried on by L. S. Berg in the Sea of Aral between the years 1900–1906 form an important contribution to the subject of limnology generally, and more particularly to this question of desiccation. The original report on these investigations (Berg, "The Sea of Aral," St. Petersburg, 1908) is published in Russian, but students unfamiliar with that tongue may acquaint themselves with the present state of knowledge concerning the whole region by means of an article by Prof. Woeikow, published in the April number of *Petermann's Mitteilungen*. Prof. Woeikow deals primarily with Berg's observations, and his maps are reproduced, but he uses information derived from other sources, for purposes of comparison.

The Sea of Aral is situated at an elevation of 50 metres above mean sea level, and its area of 63,270 square kilometres places it fourth in size amongst the inland lakes of the world. The mean depth is 16 metres, and the maximum 68 metres, depths exceeding 30 metres occurring only in one small depression in the west and two still smaller ones in the north of the basin. The volume of water is computed to be 1012 cubic kilometres, only slightly greater than that of Lake Ladoga, which has about one-quarter of the superficial area, and about one-tenth of Lake Baikal, which is little more than half the size. The supply of water comes wholly from the two rivers Amu and Syr, which together deliver, on the average, some 1500 cubic metres per second. Most of the water is derived from the melting of mountain snows, the months of maximum flow being June, July, and August. Berg gives the mean salinity as 10·75 *pro mille:* compared with analyses made during the 'seventies of last century, which yielded an average of over 12 *pro mille,* this shows a marked freshening, due, as appears, to an increased volume of water.

The survey of the Sea of Aral by Admiral Butakow in the late 'forties formed the first foundation of accurate knowledge, and there is evidence to show that at the time of that survey the level of the water was relatively high. Few precise measurements were made for a long time afterwards, but it seems certain that after the 'forties a period of falling level began, and continued for some thirty to thirty-five years. Borczow reported diminishing area in 1857. The period 1859 to 1874 is blank, or nearly so. Sewertzow, Subow, and Kaulbars (1873–4) found great shrinkage on comparison with Butakow's survey, and further comparison with the records of Meyendorff and Ewersman (1820) seemed to justify the conclusion that a general desiccation of this part of Central Asia was taking place continuously. K. Schulz, surveying in the north-eastern end of the sea in 1880, found still further shrinkage since 1874.

From 1880 to 1899, when Berg first visited the region, another blank occurs; but in 1899 Berg found a rise of level in full progress, the height already attained exceeding not only that of 1874 and 1880, but that of Butakow's records in the 'forties. Islands, for example, which appeared in Butakow's map, and which had become peninsulas in the 'seventies and 'eighties, were submerged. Working from the levels of Tillo at Karatmak, Berg estimated a height of 1·21 metres in 1901 above that in 1874. Glukhowskoy found a fall of 71 centimetres between 1874 and 1880, giving a rise from 1880 to 1901 of about 2 metres, or 9 centimetres a year. The rise has continued, and Berg now gives it as 2·75 metres in 1903, and 3 metres in 1908. The depth of the lake being mostly shallow, this rise corresponds to a very considerable increase in area; the increment in volume